U.S. scenarios to global ones, as well as the role of socioeconomic factors on demographic projections. Breakout groups in the afternoon discussed non-demographic factors within the context of demographic scenarios, as well as the importance of aligning U.S. population scenarios with global scenarios, and vice versa.

The workshop closed with a synthesis of participant suggestions. USGCRP did not intend that workshop participants reach consensus in order for the workshop to be considered successful, but rather emphasized the importance of individual contributions and viewpoints in identifying needs and potential paths forward for the science of climate change scenarios and demographics projections.

Structure of the Workshop Report

The remainder of this report is divided into four sections:

- **Section 3: Meeting User Needs for Population Projections**. This section covers the uses of population projections, user needs for projections, and projection methods for meeting these needs.
- **Section 4: Capabilities for Developing U.S. Population Scenarios**. This section reports on discussions during the workshop as participants considered capabilities for developing U.S. population scenarios, including defining and integrating different approaches, the global context for U.S. scenarios, and current capabilities to meet user needs.
- **Section 5: Key Insights from Workshop Discussions.** This section describes discussions among workshop participants regarding key issues in building scenarios of U.S. demographic change.
- **Section 6: Next Steps: Moving Forward with U.S. Demographic Change Scenarios**. This section concludes with a discussion of next steps on how to move ahead with building U.S demographic change scenarios for use in interdisciplinary analysis of social and environmental issues.

These sections are followed by references cited and four appendices that provide additional information from the workshop.

3. Meeting User Needs for Population Projections

Federal government agencies, local decision makers, researchers, and private interests use population projections to inform a range of regulatory and programmatic decisions that rely on projecting population and related variables into the future. The workshop was attended by representatives of a number of different user communities. It provided unique perspectives on the needs for population projections and methods available for meeting those needs and engendered a lively conversation on how researchers from different communities value and approach questions of uncertainty. Understanding the context in which population projections are used and the characteristics that are particularly useful for users will be important in determining how demographic scenarios and projections can be formulated to meet those needs efficiently. This section explores the issue of meeting needs from three perspectives: the role of population projections in supporting decision makers in different user communities, potential user needs for population projections, and methodologies that can be used to develop population projections that are tailored toward user needs.

User Communities

Many federal and state agencies rely on population projections to identify trends in variables and factors of interest to their missions, and as inputs into analyses designed to support the development of public policies. In addition, researchers in a variety of disciplines use population projections for both their own research and to support the development of government policy. To better understand the range of uses, the workshop included presentations and participants from federal and state government agencies and researchers from different fields. In addition, an informal review of federal agency practices with respect to projections was conducted in advance of the workshop. Collectively, the information presented and discussed at the workshop suggests both considerable breadth in the user community and variety in the uses to which population projections are put in analysis and policy development.

The Census Bureau of the Department of Commerce is a widely-used source of national population projections, which embody assumptions and projections about how the U.S. population will age over time (as far out as 2060) and change in terms of sex, race, and Hispanic origin. Population data from the U.S. Census contribute directly and indirectly to the various formulae used to distribute federal funds (Blumerman and Vidal, 2009) and are integral to projecting future funding needs and programmatic costs. Numerous agencies, including NOAA, Bureau of Land Management (BLM), EPA, Department of Transportation (DOT), Department of Agriculture (USDA), Housing and Urban Development (HUD), Social Security Administration (SSA), and Health and Human Services (HHS), use U.S. Census projections to forecast how key drivers and variables will change in the future. In some cases, U.S. Census projections are used directly, and in others, the data provide the building blocks of more detailed projections created and used by other agencies. For example, population projections play a role in the production of DOE's Annual Energy Outlook (AEO),[2] which includes variables such as vehicle miles traveled and freight demand, and in turn help drive estimates of energy use and carbon emissions. EPA uses population projections for a variety of purposes, including estimating population exposure to different pollutants or the incidence of a disease- or health-related event. At the Office of the Chief Actuary at the Social Security Administration, U.S. Census data are used in conjunction with data on mortality rates from the National Center for Health Statistics (NCHS) and the Medicare program and data on immigration to characterize the future solvency of the Old Age Survivors and Disability Insurance (OASDI) program (OASDI, 2014). U.S. Census data, along

[2] Current and past editions of the AEO are available at: www.eia.gov/forecasts/aeo/.

with other population projections and trend data, contribute to USDA/USFS projections of trends in natural resource demand and use.

In some cases federal agencies may use population projections that span a range of probable outcomes. The 2012 National Projections from the U.S. Census, for example, include a main series and three alternative series, reflecting differing assumptions about net international migration. No alternative series are currently on the Census website for the 2014 projections.

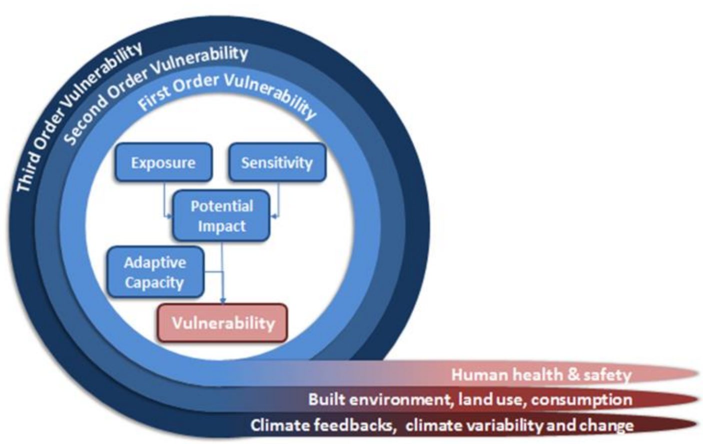
Climate change researchers inside and outside the government are another set of consumers of population projections. As described by one presenter, the community conducting impact, adaptation, and vulnerability assessments, makes assumptions about long term demographic changes in estimating vulnerabilities and impacts (see Text Box 3-1. Demographic Projections in Climate Change IAV Research). Developing population projections is particularly challenging because of the long time frame of these analyses, and a common approach is to develop scenarios that depict plausible future states of the world, in order to capture the unpredictability of the future (these issues are discussed more in Section 4 of this report).

Text Box 3-1. Demographic Projections in Climate Change IAV Research

One presenter stressed that demography is critical to understanding vulnerability to climate change impacts, but indicated that the IAV community has a distance to go in accounting for demographic change in its research. The presenter included the figure below, which illustrates how demography is a key driver of all types of climate change vulnerabilities:

- Age and sex are key factors influencing human health and vulnerability to extreme events (first order);
- The location of development and the capacity to absorb economic losses shape the vulnerability of the built environment (second order); and
- The growth of urbanized areas drives climate feedbacks (third order).

IAV research is improved by accounting for the influence of demographic change on each of the classes of vulnerability.



Source: Preston, 2014.

Like federal agencies, state and local governments and regional planners use population projections to support policy and programmatic functions, project design, and budget planning. For example, population projections may be used to develop estimates of school enrollment or to support annual appropriations within a state. State and local governments generally rely on the efforts of state demographers, who in some cases build estimates based on older U.S. Census projections (since the U.S. Census Bureau has not updated its state-level projections since 2005). Also, like national-level uses, businesses may use the projections to estimate future market shares and to plan for demographic changes in the population. According to the U.S. Census, nearly all of the states report producing population projections.[3] One presenter indicated that the resolution available in state projections generally reaches to the county level (although only rarely to the city or municipal level), noting that some detail (on age, sex, or ethnicity) may be lost as the focus narrows. Both the level of detail and the specificity in state projections is variable; some states (such as Connecticut) make use of locally derived data (such as local fertility rates), whereas other states (such as Michigan and Idaho) rely primarily on the last available state-level projections from the U.S. Census Bureau.

Data Needs for Population Projections

The diversity of user communities generates a demand for population projections that span a range of spatial, temporal, and demographic criteria. Different uses will require different demographic details or groups, different time spans for the projection, and different geographic coverage, as well as different levels of resolution and detail (ranging, for example, from national projections all the way down to municipalities or U.S. Census tracts). Some users may need both detailed and aggregate data, and so the capabilities of the user group to further refine or adapt the population projection may also determine data needs. Moreover, different user groups may need projections that represent different types of futures, (e.g., business as usual, most or least probable, or best or worst case) depending on the purposes of the projection and the analysis or policy decisions it is intended to support. Different user groups may also have a need for different levels of accuracy and precision in the projection, depending, for example, on the irreversibility of decisions that are being made, or the magnitude of the investments or other costs involved.

Conventional population projections focus on demographic variables such as age, sex, and race, and methods for projecting these variables are well-understood and commonly applied. For some purposes (such as determining environmental vulnerability or projecting health outcomes), demographic projections that include socieconomic variables—such as income or education—may be needed (see Text Box 3-2. Specialized User Needs: Public Health). These variables can be more difficult to project because they rely on behavioral factors and future policy decisions. Migration can also be difficult to project, increasing the uncertainty of projections made at small

Text Box 3-2. Specialized User Needs: Public Health

User needs may be more detailed within specialized user communities, such as public health researchers. Health impacts depend on vulnerability, which can differ greatly by age, sex, race/ethnicity, and socioeconomic factors. In the third presentation of the workshop, John Balbus of the U.S. Department of Health and Human Services noted that the health community wants whatever richness of data they can get. However, he noted that the field needs to make more investments in how best to generate and use detailed projections.

[3] According to the U.S. Census website, all states but Vermont report projections. Available at: http://www.census.gov/population/projections/data/state/st-prod-proj-list.html.

geographic scales. Thus, the uncertainty of a projection will depend on the spatial resolution, time horizon, and demographics being projected.

Discussions at the workshop stressed the tradeoffs between different characteristics of projections, as well as the directions in which needs are evolving as human systems evolve, for example, as "the urban form" changes (see Text Box 3-3. Changes in the Urban Form). Discussions also stressed that more interaction between users and producers of demographic projections is needed so that they can arrive at a common understanding of the uncertainties and limitations associated with projections of particular characteristics and time/space scales.

Text Box 3-3. Changes in the Urban Form

While the U.S. population is becoming older and more urban, participants also noted that our urban form is changing. It was suggested that there is a need to marry demography with GIS analysis. As demographers develop a better understanding of urban form, demography can be applied in other uses—such as land use and transportation—more effectively.

Three key characteristics of population projections are explored below: population characteristics, geographic scale, and time horizons.

Population Characteristics

The standard suite of variables that demographers project includes age, sex, and in some cases race/ethnicity. For many purposes, one of these variables is sufficient. For example, projections by age will allow planners to examine the future needs of different segments of the population, such as children (at different educational levels), women in their reproductive years, persons in the labor force, or the elderly. Projections by age are also essential for cost estimates and projections related to the OASDI and Medicare programs. Projections by age, sex, and race are important in health research, since dose-response—the statistical relationship between measures of exposure and measures of disease—may vary by age, sex, and race.

User needs for population characteristics range from simple overall projections to projections with considerable demographic and socioeconomic details. Workshop participants identified a variety of population characteristics that go beyond the standard suite of variables, but which could be critical to some analyses and planning efforts. Participants identified variables such as educational achievement (see Text Box 3-4. Challenges and Tradeoffs in Meeting User Needs: Education), urban/rural classifications (see Text Box 3-5. Urban vs. Rural), health status, and income were among those identified. In some cases, the need for population projections can become quite

Text Box 3-4. Challenges and Tradeoffs in Meeting User Needs: Education

Some participants indicated a strong need for projections of educational attainment, and recent work has shown the importance of education in many analyses, including studies of vulnerability to natural disasters (Butz et al., 2014). However, other participants emphasized the tradeoff between the population characteristics being projected and the geographic scale of the projection; due to data limitations and the increasingly important role of migration, small scale projections cannot reliably include as many population characteristics as larger-scale projections can.

complicated, necessitating more sophisticated methods. For example, analyses involving construction demand, property taxes, or emergency evacuation planning may require data and projections for households rather than simply numbers of people, including information on permanent vs. seasonal residences, households by living arrangement (married, children, single, elderly), and types of housing units. Alternatively, assessing vulnerability to coastal flooding requires understanding and projecting patterns of land use, including transportation modes and usage and trends in urbanization. Even for a given variable, categories of interest may vary significantly from one use to another. For example, one project may rely on total population and housing units for municipalities with particular characteristics (e.g., small vs. large), while another may rely on information on population and housing density on a neighborhood scale.

Text Box 3-5. Urban vs. Rural

Some participants noted that it is important to treat urban and rural areas differently, as the processes of change can vary greatly between urban and rural areas. Others felt it was more important to think about an urban/rural continuum, and not separate them.

As projections expand beyond conventional demographic variables to socioeconomic variables, the pathways are less well understood and, consequently, demographers may consider projections to be more uncertain. For some socioeconomic characteristics, it can be extremely difficult to obtain detailed data both at fine scales and for the nation as a whole, further challenging demographers' abilities to meet user needs for data. While users expressed a need for sophisticated and detailed projections, some demographers at the workshop pushed back strongly, questioning whether variables such as education can be reliably projected at the local level. While certain uses may benefit from more detailed population characteristics and more granular availability of data, participants agreed that there is a tradeoff between detail and uncertainty, especially with regard to socioeconomic characteristics such as education, health status, and income. Some participants even questioned why there would be a need for anything more detailed than age, sex, and race, given the inherent uncertainties.

Geographic and Temporal Extent and Resolution

The extent and resolution of a projection will influence both its uncertainty and its saliency to its users. Both geographic and temporal extent are important. Presentations and discussants explored these issues in detail, both from the perspective of what user needs are, and how uncertainty necessitates tradeoffs between meeting these needs and providing accurate and precise results.

Potential user needs for population projections cover a broad spectrum of geographical resolutions, including national, state, county, and sub-county outcomes, such as municipalities. Many federal programs and policies use national, regional, or-state-level data. For example, the Energy Information Administration of DOE uses regional (multi-state) and national population projections as inputs into energy demand projections for the *Annual Energy Outlook*. As another example, the USDA's *Southern Forest Futures Project* projects changes in southern forests between 2010 and 2060 under different scenarios using state population estimates, among other inputs. Analysis and research to support federal programs and policies, as well as "one-off" reports and analyses, may use more detailed county or even sub-county data and projections. For example, at the request of local stakeholders, the Bureau of Land Reclamation conducted a study of water demand and water supply conditions in Coconino Plateau region, out to the year 2050; the study used a combination of U.S. Census, state, and local data sources. Analyses conducted by state and local governments will generally rely on more detailed geographic projections that are informed by a detailed knowledge of local economic and regulatory factors; a national agency may not have a need for the high level of resolution that cities and MPOs will require in approaching and analyzing their study area.

The time horizons over which population projections are used by departments, agencies, and offices within the U.S. Federal government typically range from as short as a decade (i.e., to 2025) to almost a century (2100), according to the informal review conducted before the workshop. The time horizon will be dictated by the analysis or policy that the projection is supporting, or the period for which planning or budgeting activities are being undertaken. For example, the Department of Housing and Urban Development has used short- to medium-term projections (i.e., to the year 2050) of the percentage of the population that will be age 65+, in order to understand the demand for affordable and accessible housing over time. By contrast, studies looking at the solvency of the social security system typically have much longer time horizons (to 2085 or 2100). Similarly, studies and policy analyses looking at climate change, both mitigation and impacts/adaptation, also focus on longer time frames (to 2100 or longer).

Geographically, local level populations are easily affected by specific local land-use policy and local economies; however, these effects tend to even out over larger geographic scales. Consequently, methods for projecting national population may be different from methods to project population at the state or county level, where economic, social, and other factors come into play and detailed micromodels can be employed. Depending on the data inputs, modeling capabilities, and available resources, projections may be more or less uncertain at different levels. Similarly, it is easier to project what will happen to population in the near term than over the long term. Moreover, as described above, expanding the set of socioeconomic categories for which population is projected equally expands the methodological complexity of the projection. At the same time, these layers and levels of detail—geographic, temporal, and characteristics—are often what policy makers and decision makers need.

While national or global projections may sometimes be made over the very long term, projections for smaller areas are generally limited to a decade, or perhaps 30 years at most; as a projection's time horizon expands and the geographic focus narrows, uncertainty increases. One presenter illustrated the uncertainty of increasing the spatial resolution and temporal extent of a projection, using mean absolute percent errors.[4] Mean absolute percent errors are a common measure of projection uncertainty, and indicate the reliability with which the user may want to view the projection. In Table 3-1, mean absolute percent errors increase significantly with the length of the time horizon and as the geographic unit shrinks. When time horizon and geographic scale are combined, mean absolute percent errors grow considerably. The presenter indicated that although uncertainty is unavoidable, there are different ways to accommodate it. One method is to include alternative projections; for example, the U.S. Census Bureau releases alternative low, medium, and high series, reflecting different assumptions about migration. Some demographers noted that they might conduct a sensitivity analysis and attach the results to a report. Providing prediction intervals (i.e., an estimate of the range into which future populations might fall based on a certain level of confidence) also provides users with a better understanding of the uncertainty involved in any projection exercise.[5]

Table 3-1. Mean absolute percent errors of projections, by length of horizon (years) and geographic unit

Length of Horizon	States	Counties	Census Tracts
5	3	6	9
10	6	12	18
15	9	18	27
20	12	24	36

Source: Smith, 2014.

Presenters and discussants at the workshop discussed the issues of uncertainty and confidence in some depth. Demographers, whose work is commonly used to support policy and budget decisions, were reluctant to make projections that were associated with a high degree of uncertainty, as would be the case for socioeconomic details or projections far in the future. While some participants suggested that scenarios could be useful in managing uncertainty, others were more skeptical, asking "who would actually use scenarios for decision making?" One pointed out that the tradeoff between time horizon and uncertainty is already understood by policy makers, stating that in situations where policy and budget decisions require a relatively high degree of certainty, users rarely look beyond than 20–40 years into the future (e.g., investments in transportation infrastructure); beyond that time period, the uncertainties are too great.

Discussants pointed out that climate change research is one of the exceptions, in that research and analysis of the consequences and policy alternatives for mitigating or responding to climate change generally look far into the future. For example, models such as the Global Change Assessment Model and other integrated assessment models, as well as the reports and analyses

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[4] Mean Absolute Percent Error (MAPE) is a common measure of projection error. MAPE is the mean of the absolute percentage errors. The absolute percentage error is the absolute value of the difference between the projected value and the actual value, calculated as a percent of actual. MAPE tells us how large an error we can expect from the projection on average.

[5] The 2012 population projections include the alternative series, but no alternatives are currently available on the Census website for the most recent 2014 projections. See www.Census.gov.

generated by the National Climate Assessment, extend to 2100. While participants were concerned about the high degree of uncertainty inherent in long-term projections, many agreed that the long lasting effects of climate change give rise to research questions that can only be answered using long temporal horizons.

As a result of needs specific to long-term studies, some users have adopted the scenario approach as a way to embrace and understand the impact of the uncertainty inherent in long-term projections. These issues are discussed in Section 4: Capabilities for Developing U.S. Population Scenarios.

Meeting User Needs: Projection Methods for Estimating Population

A variety of methods are available that project population at different levels of resolution and scale, and capture different population groups and characteristics. At the national level, population projections in the United States commonly use the cohort-component method. This rather intuitive approach starts with population estimates for the number of individuals of each age in a base year, and then base population is advanced each year using projected survival/mortality rates. Each year, a new birth cohort is added to the population by applying projected fertility rates to the female population, by age. One presenter pointed out that this method is not as robust at the sub-national level, however, because of the difficulty of capturing migration, which is particularly important when projecting spatial detail. Movements from one sub-national area to another are less predictable, and are more likely to be driven by economic or amenity factors. Several of the presenters pointed to a wide variety of methods (see Table 3-2, at the end of this section) that are available for projecting population at the subnational level. These methods range from relatively simple methods based on historical patterns and trends to more sophisticated methods that try to model, or simulate, the changes in the drivers of behavior.

More than one method can be used for a given purpose, and participants at the workshop spent considerable time discussing alternative methods and their strengths and weaknesses, as well as the factors that contribute to selecting a methodology. Key factors identified by participants included the ease of use and transparency of results, the quality of input data available, and the desired scale and time horizon. For example, one presenter noted that trend extrapolation methodology, which is fairly easy to implement, is often used at the local government level for population projections, in part because budgets may not allow for more sophisticated methods. Simpler methods may not only be more cost effective, but they may also be easier to communicate. Approaches are not necessarily mutually exclusive. Moreover, in some cases, a study may use multiple projection methods side by side; for example, the North Central Arizona Water Study (Pinkham, 2002) uses both a cohort-component method as well as a linear extrapolation of current growth to produce separate estimates of population growth that can be compared and contrasted.

Key Points: Meeting User Needs for Population Projections

1. User communities that span all levels of government and the private sector create a need for population projections that span a range of geographic scales and resolutions, time horizons, and population characteristics.

2. Diverse user communities and types of applications of population projections make it difficult for a "one size fits all" approach that satisfies the variety of needs.

3. In some cases, users can include a range of alternative projections, reflecting different futures with respect to migration or other key variables.

4. Increasing levels of uncertainty are associated with projections over a longer time horizon or at finer geographic resolution.

5. The choice of appropriate methodology will depend not only on user needs for specific population projections, but also on resource constraints, data availability, and the importance of communicating methods and transparency.

Table 3.2. A summary of projection methods discussed at the workshop

Method	Description	Examples of Uses	Key Characteristics	Citation
Proportional Scaling	Use one or more data sets to disaggregate data geographically or interpolate additional population characteristics by scaling proportionally between datasets.	Downscaled global SRES scenarios at the national and grid levels (van Vuuren et al., 2007).	• Easy to implement but difficult to capture complex processes.	Jones, 2014
Trend Extrapolation	Can be used for total population or component (e.g., race). Applied to ratio as well (ratio of county to state). Commonly used for local counties where there may be limited options.	The Hamilton-Perry method for projecting change based over a short period using minimal data inputs (Hamilton and Perry, 1962).	• Easy to implement but difficult to capture complex processes. • Assumes past is a good predictor of the future, so it won't capture divergences from past patterns. • May not have variables of interest. Does not capture structural changes.	Jones, 2014; Smith, 2014
Gravity-based	Gravity models calculate the potential suitability or desirability of each location. Variables for such models usually include total population and geographic suitability. Migration between two geographical points is then determined by these variables.	Spatially explicit interpretations of scenarios from SRES (Grübler et al., 2007).	• Accounts for population counts and geographic suitability. • Does not formally account for demographic behaviors, births, deaths, migration—or socioeconomic conditions, but there is potential to.	Balk, 2014; Jones, 2014
Hybrid Models	Combines multiple methodologies to project demographics.	EPA's ICLUS model combines the cohort-component approach with a gravity model for migration. (U.S. EPA, 2009)	• Incorporating multiple methodologies can address limitations of individual methodologies. • More resource intensive to implement.	Jones, 2014
Cohort-Component	Population is usually divided into age/sex groups. The drivers for each group are: 1. Base population. 2. Baseline fertility, mortality, and migration rates. 3. The future fertility, mortality, and migration rates. This method is used most frequently.	Census Bureau Projections (U.S. Census Bureau, 2012).	• Most data requirements are not too difficult to acquire. • Migration data can be difficult to come by, and migration patterns are not as stable as other variables. • Difficult to incorporate socioeconomic factors, such as employment and economic growth.	Balk, 2014; Smith, 2014
Structural Models	A demographic variable is projected based on historical values and external variables. Also commonly used. Common variables include job growth, land use, housing, and local services.	Can be applied to projecting populations for small areas, where other techniques are less reliable (Chi and Voss, 2011).	• Growth is measured, but demographic components are not. • Better for short-term projections. • Used for local-area projections.	Balk, 2014; Smith, 2014

Method	Description	Examples of Uses	Key Characteristics	Citation
Microsimulation (Agent-based Modeling)	Used on small areas. Focus on individual households or people. Each individual is separate in the model. Aggregate behavior is based on the sum of individual behavior.	Duleep and Dowhan (2008) proposed improving OASDI projections by adding immigrants to microsimulation models.	• Limited in geographic scope and can be expensive to develop. • Able to incorporate much detail through individual decision-making. • Used largely for planning purposes.	Smith, 2014
Spatial Diffusion	Models spread of population over space and time as population spreads to less populated areas. Accounts for density constraints and other geographical features. Regions react to other regions (used by geographers and planners).	Can be used to understand the effects of social learning and social influence on demographic changes (Montgomery and Casterline, 1996).	• Used largely by geographers and planners.	Smith, 2014